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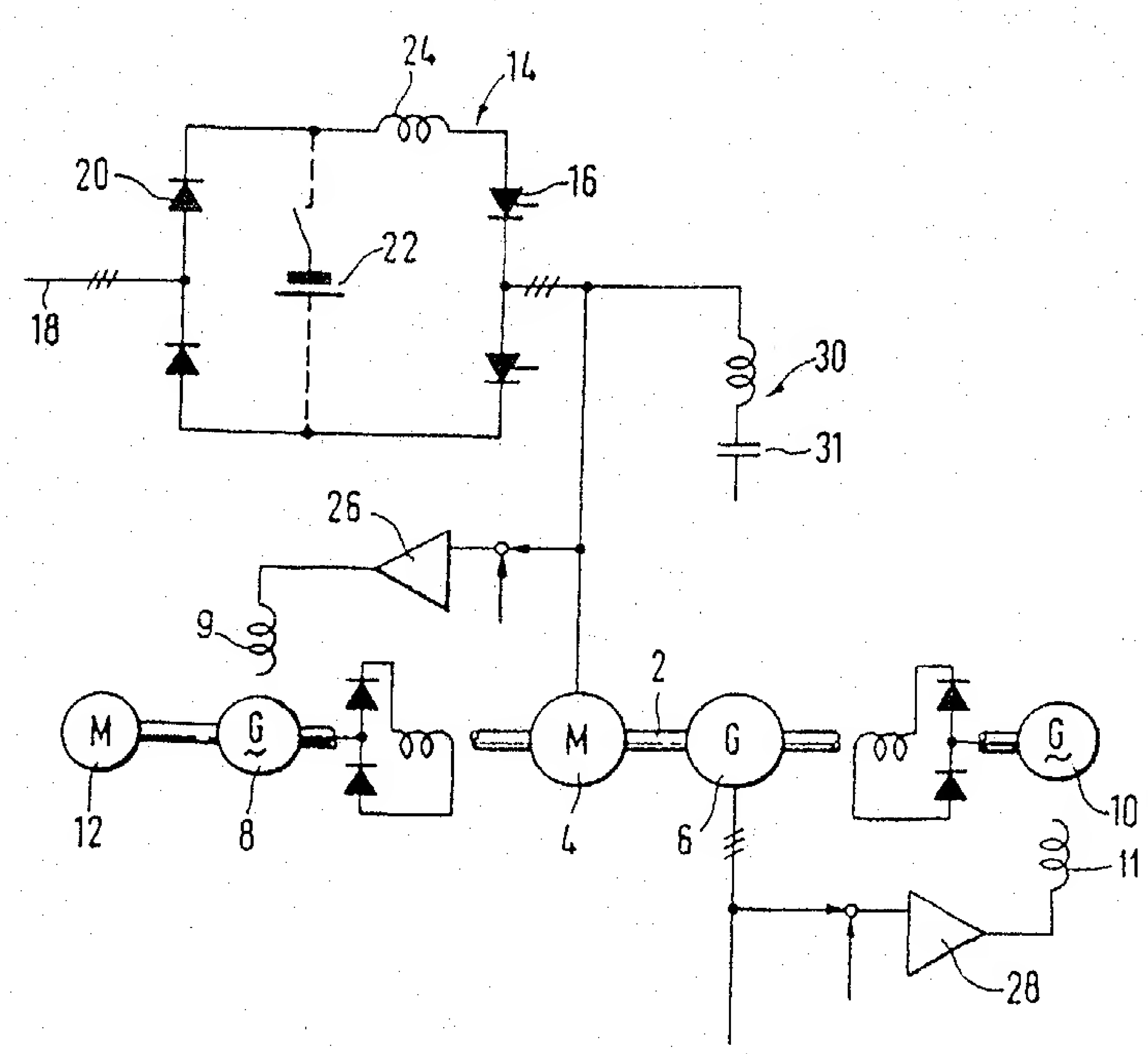
(54) Converter System

(57) The system includes a motor/generator assembly in which a three-phase synchronous motor 4 is coupled to a synchronous generator 8. A DC supply is applied to an inverter circuit 14 which gives a three-phase output to the motor 4. The inverter circuit 14 includes controllable rectifiers 16 which are controlled by firing pulses orientated in phase relationship with the terminal voltage of the motor 4. The DC supply may be provided by further rectifiers 20 or a battery 22.



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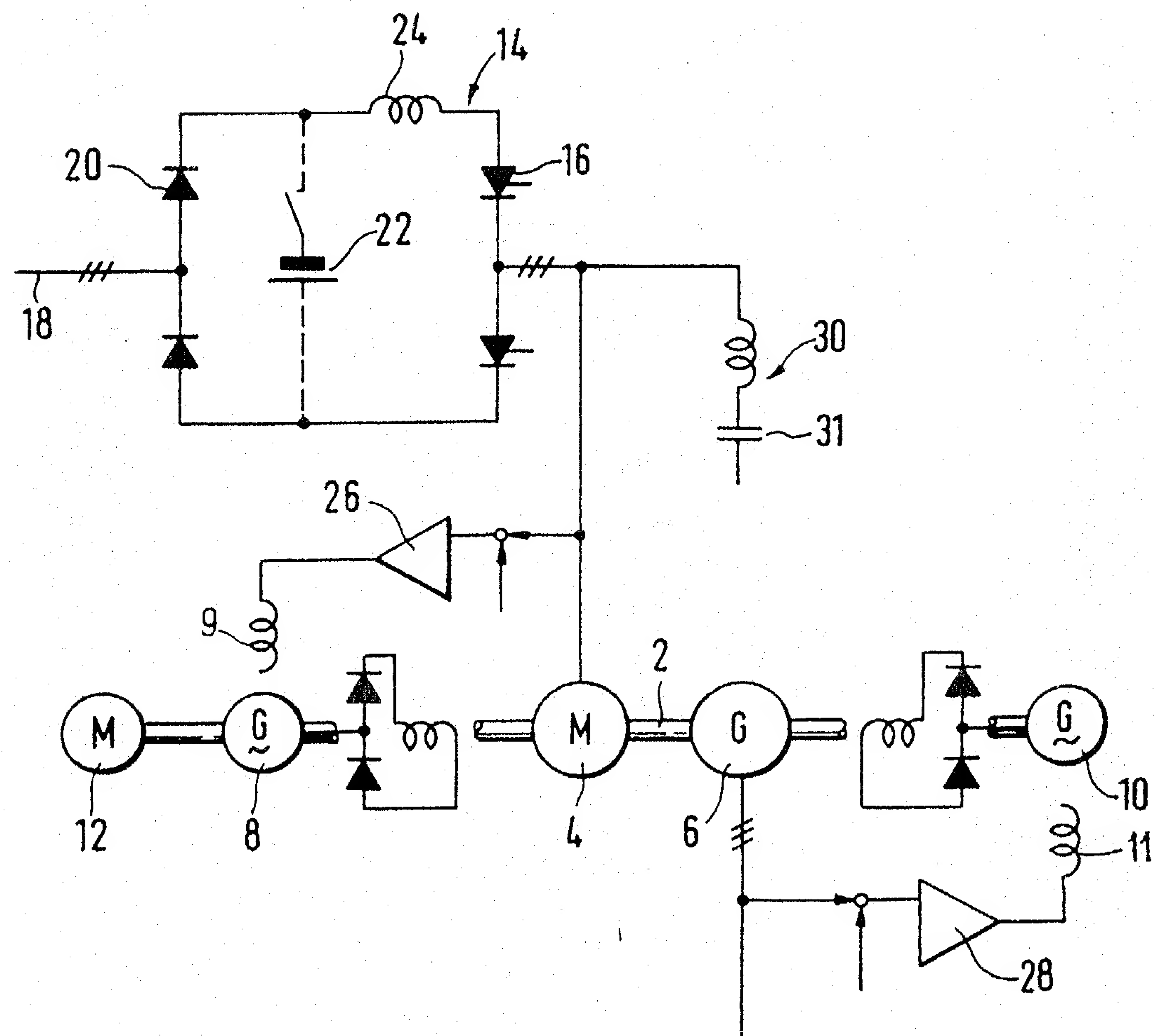

SPECIFICATION
Converter System

The invention relates to a converter system including a three-phase motor which is coupled with a synchronous generator.

Converter systems of this type are used as power supply stabilisers, frequency converters and in uninterruptable power supply installations.

A power supply stabiliser is a motor/generator of which the generator supplies a secondary power supply to which high-priority and sensitive loads are connected. A complete separation between the secondary power supply and the primary power supply is achieved by means of the motor/generator and any disturbances which appear in the primary voltage, such as voltage peaks, overvoltages or voltage drops are isolated from the secondary power supply. Due to the energy stored in the rotating masses of the motor/generator, short period interruptions in the primary power supply are not transmitted to the secondary power supply. It is known to use a synchronous or an asynchronous motor as the driving motor in a motor/generator to be used as a power supply stabiliser. The generator of a motor/generator, used as a power supply stabiliser has hitherto preferably been a synchronous generator having brushless excitation.

Where the primary and secondary frequencies are not equal the motor/generator will act as a frequency converter. The different frequencies may be produced at equal rotational speeds of the motor and generator by their having different pole numbers. It is also known to introduce a difference in rotational speed between the generator and motor by means of gears. Yet another way in which the different frequencies can be accommodated is by means of a mixed system in which the difference in frequency is produced, on the one hand, by means of different pole numbers in the motor and generator and, on the other hand, by means of intermediate gears between the generator and motor. If the secondary frequency is close to the frequency of the primary supply, as for example in the conversion from 50 to 60 Hz, the avoidance of gears leads to high numbers of poles in the motor and generator which, like gear systems, have a disadvantageous effect on the constructional size, weight and cost of the motor/generator. Synchronous or asynchronous motors may be used as the driving motors in frequency converters. In other respects, frequency converters exhibit the properties of power supply stabilisers.

A disadvantage of known converter systems is that in the event of mains failure a synchronous or an asynchronous motor used as the driving motor is able to continue to operate as a generator and feed considerable power back into the primary grid. This feedback of power is drawn from the load. This leads to a considerable decrease in the ride-through time available during failure of the power supply.

On the other hand, on re-establishment of the power supply, high current surges occur in the primary power supply, particularly where the motor is an asynchronous motor, and these may trip circuit breakers connected in series with the motor. In addition, particularly in the case of a synchronous motor, it is necessary to employ synchronisation devices which permit reconnection at phase coincidence only.

In a motor/generator which is intended to ensure an uninterrupted supply of power, the drive motor must be fed from a battery during mains failures. D.C. motors are preferably used for such systems as the frequency of the secondary power supply can be kept constant by controlling of the exciter current independently of the voltage and frequency of the mains supply.

On account of the large time constant of the exciter it may be necessary to have additional stored energy by means of a flywheel to provide satisfactory response characteristics on disturbance conditions. Particularly in the case of high power ratings it is then necessary to provide additional separate bearings for the flywheel. It is an object of the invention to provide a converter system which can be operated as a power supply stabiliser, as a frequency converter and also as an uninterrupted power supply, which can be constructed to be of the brushless, single housing type of motor/generator and which will exhibit good control characteristics even without additional flywheels.

According to the invention the converter system comprises a three-phase synchronous motor and an inverter circuit having an input to be connected to a direct current supply and an output providing a three-phase alternating current to be applied to the motor, the inverter circuit including controlled rectifiers being controlled by firing pulses oriented in phase relationship with the terminal voltage of the motor.

The converter system according to the invention has the advantage that feedback of power is impossible in the case of failure of the supply source and that no uncontrolled current surges occur on re-establishment of the supply source.

The DC supply source may be derived from an AC supply by an uncontrolled rectifier means. Alternatively the DC supply source may be a battery which could be brought into use on failure of said AC supply source.

An embodiment of the converter system in accordance with the invention is illustrated in the accompanying drawing, which also includes a circuit diagram, and is described in detail in the following with reference to the drawing.

The rotors of synchronous motor 4 and a synchronous generator 6 are mounted on a common shaft 2. The motor 4 and the generator 6

exciter 10 for the synchronous generator 6 are arranged with their rotors on the common shaft 2. The rotor of a starting motor 12 is coupled with or may be mounted on the common shaft 2.

The synchronous motor 4 is connected to an inverter circuit 14. The inverter circuit 14 which supplies the synchronous motor contains controlled rectifiers 16. The DC input of the inverter is fed from an uncontrolled rectifier circuit 20 which is supplied by a three-phase source 18. Where necessary, for example in systems for the uninterrupted power supply, a battery 22 is also provided across the rectifier circuit 20. A smoothing reactor 24 is provided in the rectifier circuit. Instead of providing the battery 22, a direct current power supply may be applied. The rectifier circuit 20 may be designed for six-pulse operation. Twelve-pulse operation is also possible, for example by the use of a three-phase isolating transformer having two secondary systems isolated from each other and which are offset by 30 electrical degrees relative to each other. The primary power supply is therefore maintained free from harmonics to the greatest possible degree since for practical purposes only harmonics of the 11th and 13th order remain undamped at 9% and 7,5% of the fundamental component respectively.

Since the rectifiers 20 are uncontrolled, the voltage of the intermediate direct current part of the rectifier circuit is directly proportional to the voltage of the electrical mains supply 18.

The voltage of the intermediate direct current part of the rectifier circuit is re-converted to a three-phase AC voltage by means of the controlled rectifiers 16, e.g. thyristor-rectifiers in a three-phase bridge connection which is connected on its three-phase side to the synchronous motor 4.

The controlled rectifiers 16, which form the inverter 14 provide the active power necessary to drive the synchronous motor.

The reactive power required by the inverter 14 is supplied from the synchronous motor 4. Since the synchronous motor 4 is operated at a constant rotational speed and constant voltage firing of the controlled rectifiers 16 can be performed directly in relationship with the terminal voltage of the synchronous motor 4. The active current consumption of the synchronous motor 4 and thus its torque can be controlled by controlling the onset of firing of thyristors or other controlled rectifiers in relation to the terminal voltage of the synchronous motor 4. At constant motor voltage and constant rotational speed, the torque is practically speaking proportional to the current flowing in the intermediate direct current part of the circuit.

Control of the rotational speed of the motor 4 can thus be carried out in a known manner, as in a thyristor-supplied direct current drive, by means of a rotational speed regulating circuit with a subordinated current control circuit. The current control circuit provides a fast-operating current possibility to include a current feedback signal to compensate for generator load changes prior to a frequency change taking place. A transistor voltage regulator 26, which draws its working voltage partly from the terminal voltage of the synchronous motor 4 and partly from the voltage of the mains supply 18, serves for the control of the motor voltage by means of the field winding 9 of the exciter generator 8. A reliable excitation of the synchronous motor 4 in all circumstances is ensured by this means.

The additional power due to the reactive power and that due to current harmonics of the inverter circuit must be taken into account in the design of the stator winding of the synchronous motor 4.

The synchronous generator 6 may be constructed, like the synchronous motor 4, as a salient pole machine having brushless excitation. Its transistor voltage regulator 28, which controls the field winding 11 of the exciter generator 10, is partly fed from the terminal voltage of the generator 6 and partly from the voltage of the mains supply 18.

The starting motor 12 may be an asynchronous motor. When only direct current is available for use, the starting motor 12 may also be designed as a direct current motor. Hydraulic or pneumatic motors may be used as the starting motor if the necessary driving media are available for use.

The synchronous motor 4 may also be started asynchronously in a known manner.

The current harmonics produced by the inverter circuit 14 can be suppressed by the inclusion of filter circuits 30, which are preferably designed as out of phase series resonance circuits having frequencies lying between those of the fifth and seventh harmonics. At fundamental frequency these filters act as a capacitor. Particularly favourable relationships arise when the filter capacitor is so dimensioned that it provides reactive power for the inverter.

In an arrangement of this type, the current harmonics and the reactive current in the motor are substantially reduced and the efficiency of the system is improved. An improvement in the efficiency can also be achieved in that the filter capacitor provides part of the no load excitation so that it is possible to operate with a lower excitation power.

In operation, after the system has run up to approximately the rated rotational speed and the synchronous motor has been excited to the rated voltage, firing of the thyristors of the inverter circuit is started. With constant flux in the synchronous motor 4 the current in the direct current part of the circuit corresponds to the torque of the motor. The inverter circuit thus supplies the necessary torque for the maintenance of the rotational speed and, in particular, when the load is fluctuating, by controlling the active current in the motor. In contrast, the reactive power necessary for operation of the controlled rectifiers 16 is supplied from the synchronous motor 4.

combination in comparison with known arrangements is that during start-up of the system it is unnecessary to provide special means for the forced commutation of the controlled rectifiers 16 in the neighborhood of standstill and that means for the firing of the rectifiers 16 as a function of the position of the rectifiers 16 as a function of the position of the exciter poles are not required. Firing of the controlled rectifiers 16 can be carried out in the simplest manner as a function of the alternating voltage, that is as a function of the voltage of the motor 4.

The secondary frequency of the converter system described is totally independent of any primary frequency changes since the system is only D.C. coupled.

In the case of interruption of the mains supply or fall in voltage of the supply below permissible values, the controlled rectifiers are immediately controlled to minimum firing angle. In this way it is possible to achieve a problem-free automatic restart after recovery of the mains supply provided the rotational speed has not already fallen to too low a value.

Claims

1. A converter system comprising a three-phase synchronous motor, a synchronous generator coupled to the synchronous motor and an inverter circuit, the inverter circuit having an input to be connected to a DC current supply; output means providing a three-phase current to be applied to the motor; controllable rectifier means being controlled by firing pulses oriented in phase relationship with the terminal voltage of the motor.

2. A converter system according to Claim 1, including a common shaft on which the rotors of the synchronous motor and the synchronous generator are mounted.

3. A converter system according to Claim 1, in which brushless excitation means is provided in association with each of said synchronous motor and said synchronous generator.

4. A converter system according to any preceding claim including a harmonic wave filter comprising a series resonance circuit in parallel with the terminals of said synchronous motor and arranged between said inverter circuit and said synchronous motor.

5. A converter system according to Claim 4, in which the resonance frequency of the harmonic wave filter lies between the frequencies of the fifth and the seventh harmonics.

6. A converter system according to Claim 4 or 5 in which the performance of the harmonic wave filter at the fundamental frequency is designed to provide reactive power for the inverter circuit.

7. A converter system according to any preceding claim in which means providing said DC current supply includes an uncontrolled rectifier circuit connected at its alternating current input to a three-phase current supply and at its direct current output to the direct current input of said inverter circuit.

8. A converter system according to Claim 7 in which said uncontrolled rectifier circuit is designed to be six- or twelve-pulsed.

9. A converter system according to Claim 7 in which said inverter circuit is connectable to a battery providing said direct current source.

10. A converter system according to Claim 1 including a starting motor for starting-up said synchronous motor.

11. A converter system constructed and arranged substantially as described herein and shown in the accompanying drawing.

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